(12) UK Patent Application (19) GB (11) 2 272 980 (13) A

(43) Date of A Publication 01.06.1994

(21) Application No 9324292.3

(22) Date of Filing 25.11.1993

(30) Priority Data
(31) 103900 (32) 26.11.1992 (33) IL

(71) Applicant(s)
El-Op Electro-Optics Industries Ltd

(Incorporated in Israel)

PO Box 1165, Rehovot, Israel

(72) Inventor(s)
Abraham Reichert

(74) Agent and/or Address for Service
Frank B Dehn & Co
Imperial House, 15-19 Kingsway, LONDON, WC2B 6UZ, United Kingdom

(51) INT CL^5
G02B 27/14

(52) UK CL (Edition M)
G2J JBSX1 JHU

(56) Documents Cited
GB 2208014 A GB 1584268 A GB 1364496 A
US 5050962 A US 4830464 A

(58) Field of Search
UK CL (Edition M) **G2J JBSX1 JB7X16 JHU**
INT CL^5 **G02B**

(54) Optical beam splitting lens

(57) An integrated optical system for the simultaneous viewing of scenery 40 and of informative data 38 superpositioned on said scenery, consists of a lens 30 divided into two parts by a beam splitter 36, said lens having a first surface 31 facing the viewer, and a second partially reflecting convex surface 32 on the main optical axis 33, defining a partially reflecting concave mirror 32' facing the first surface, said lens having a third surface 37 parallel to the main optical axis or at an acute angle therewith, facing the source 38, said beam splitter 36 extending from the upper part of the first surface 31 to the lower part of said concave mirror 32', so that the source of the data is at the focus of the said concave surface, so that the beam coming from the data source 38 enters through the third surface, is reflected by the beam splitter toward the said partially reflecting concave mirror and from this via the beam splitter to the first surface to the eye 39 of the viewer. Lens 30 may have zero power (Figs. 3, 4, 8) and may be a doublet (Figs. 4, 5, 8).

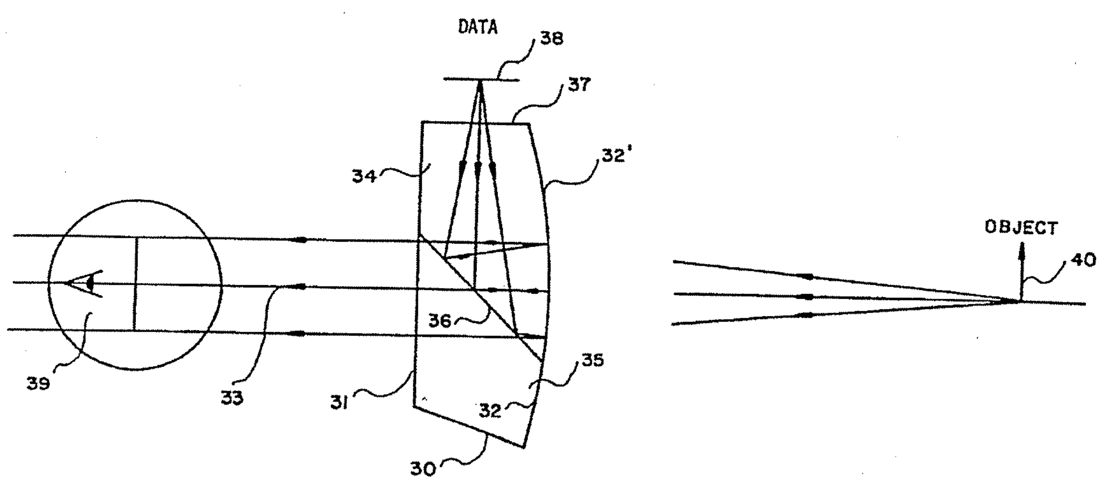

FIG. 2

GB 2 272 980 A

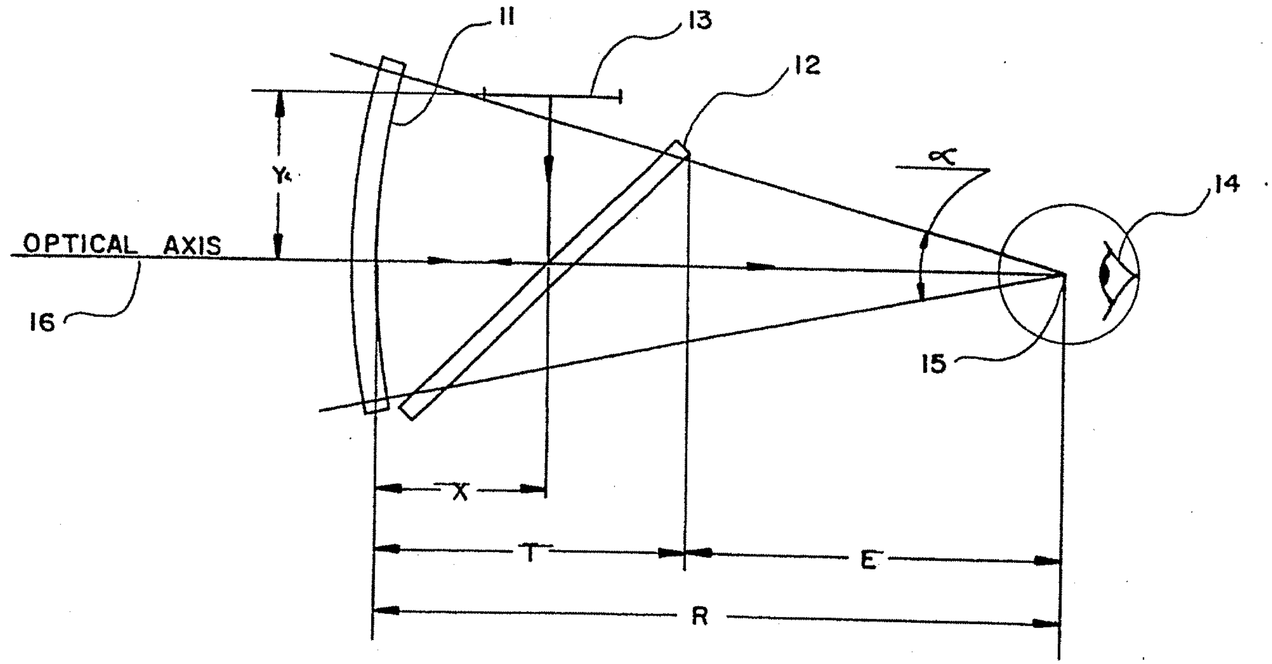

FIG. 1A

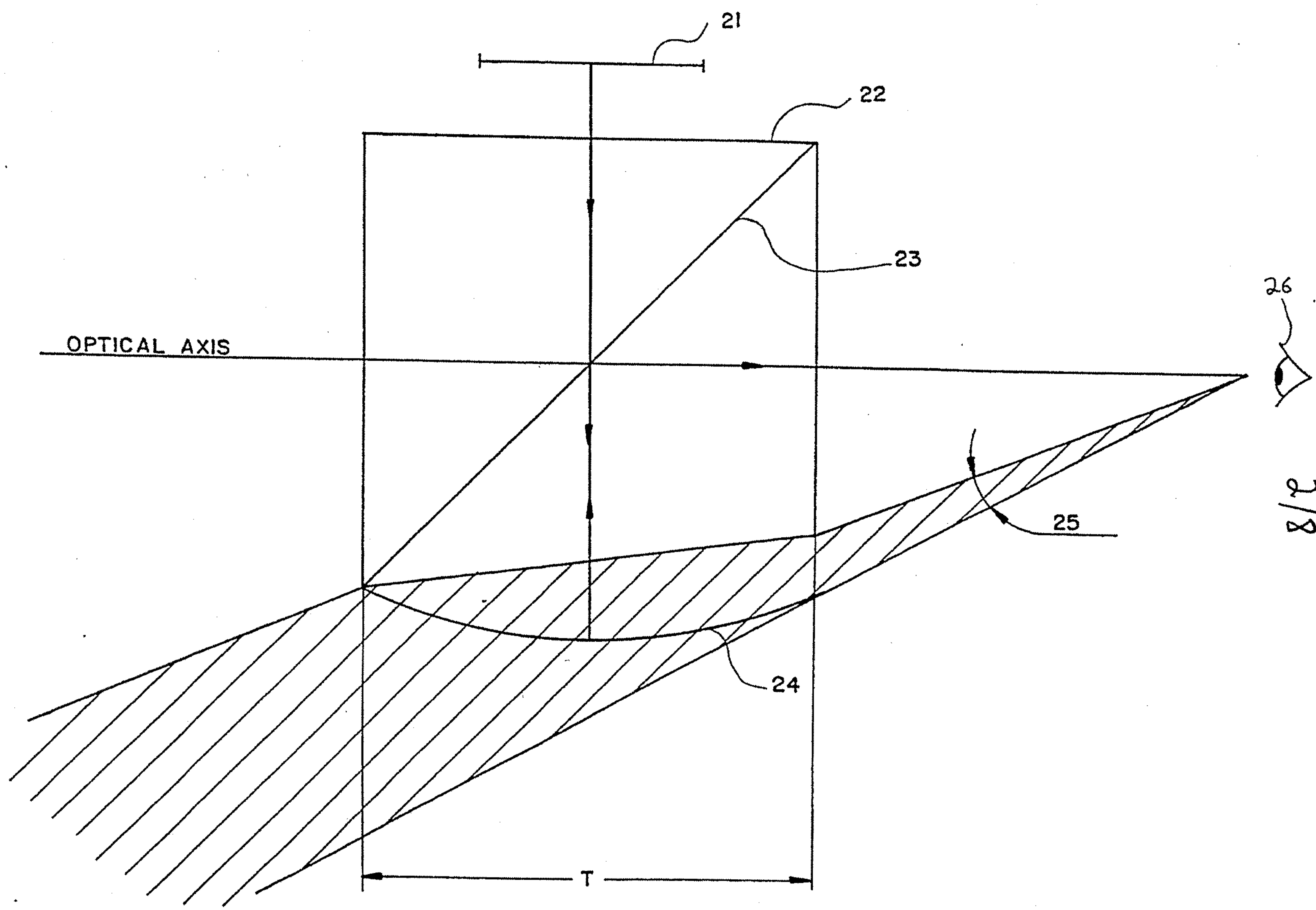

FIG. 1B

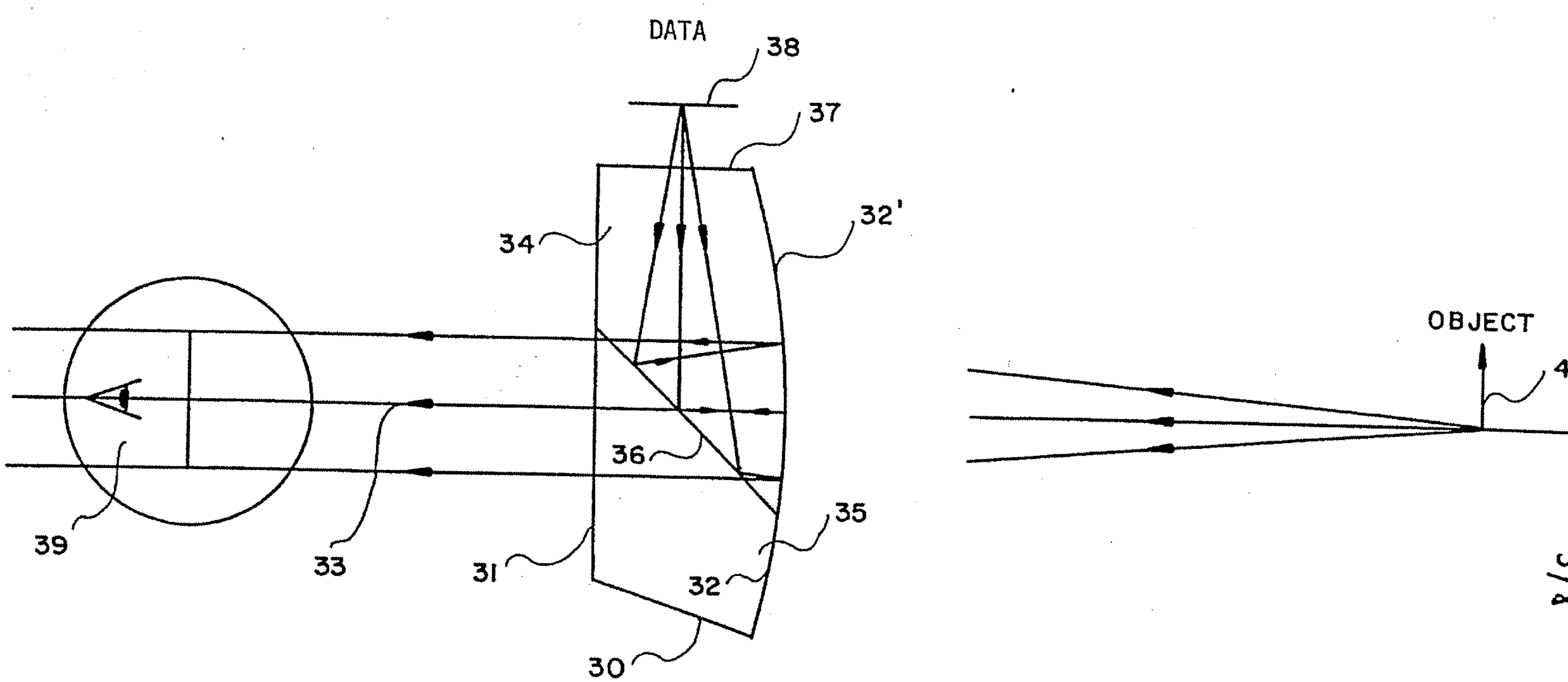

FIG. 2

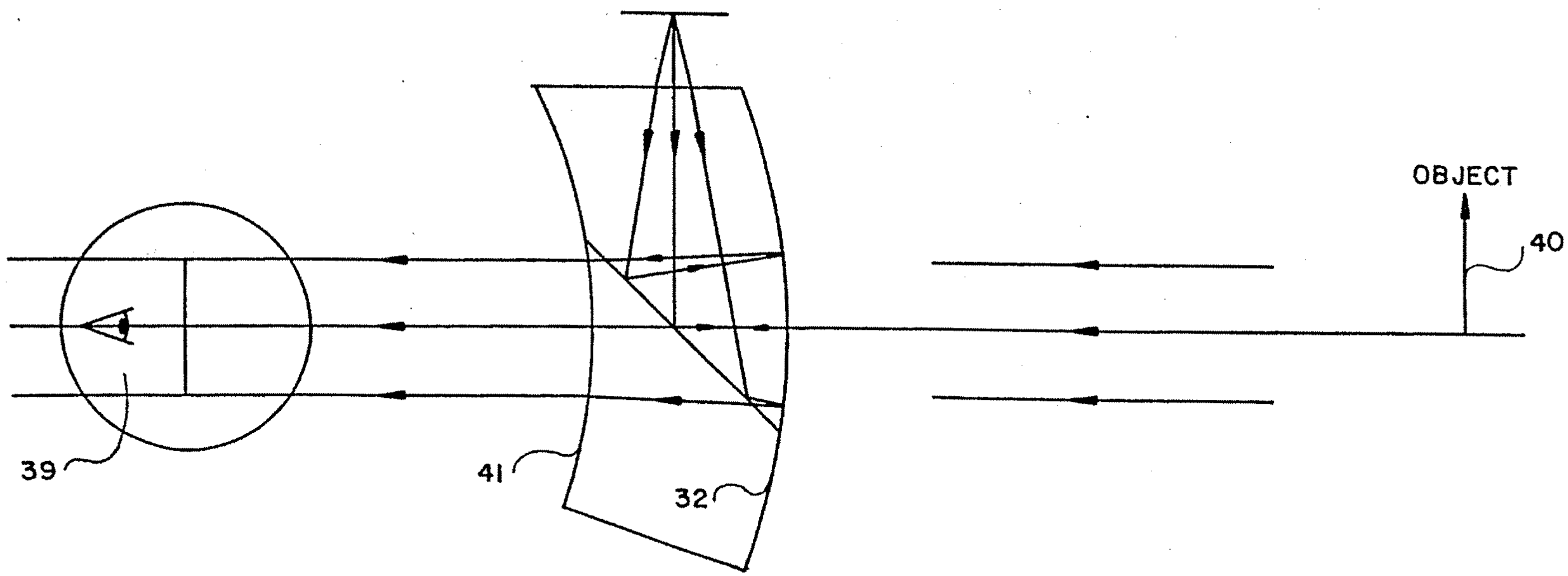

FIG. 3

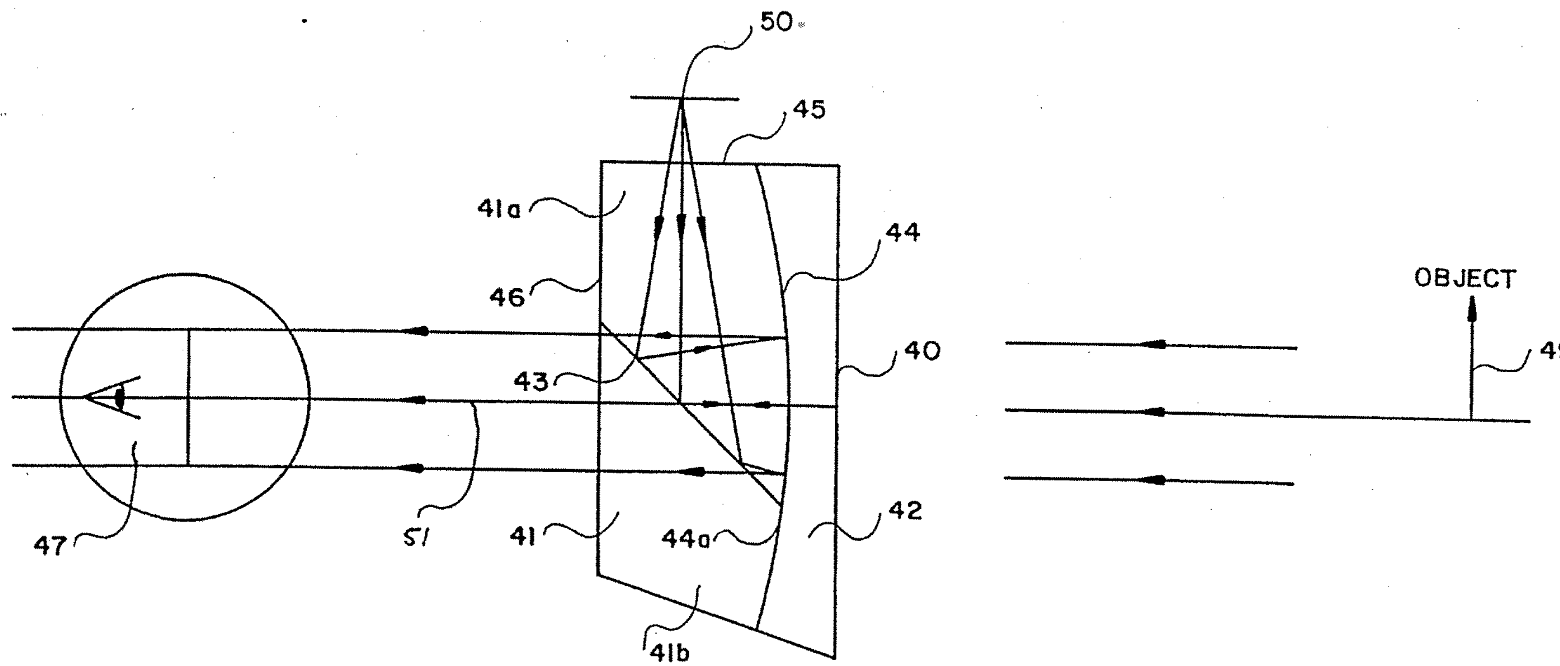

FIG. 4

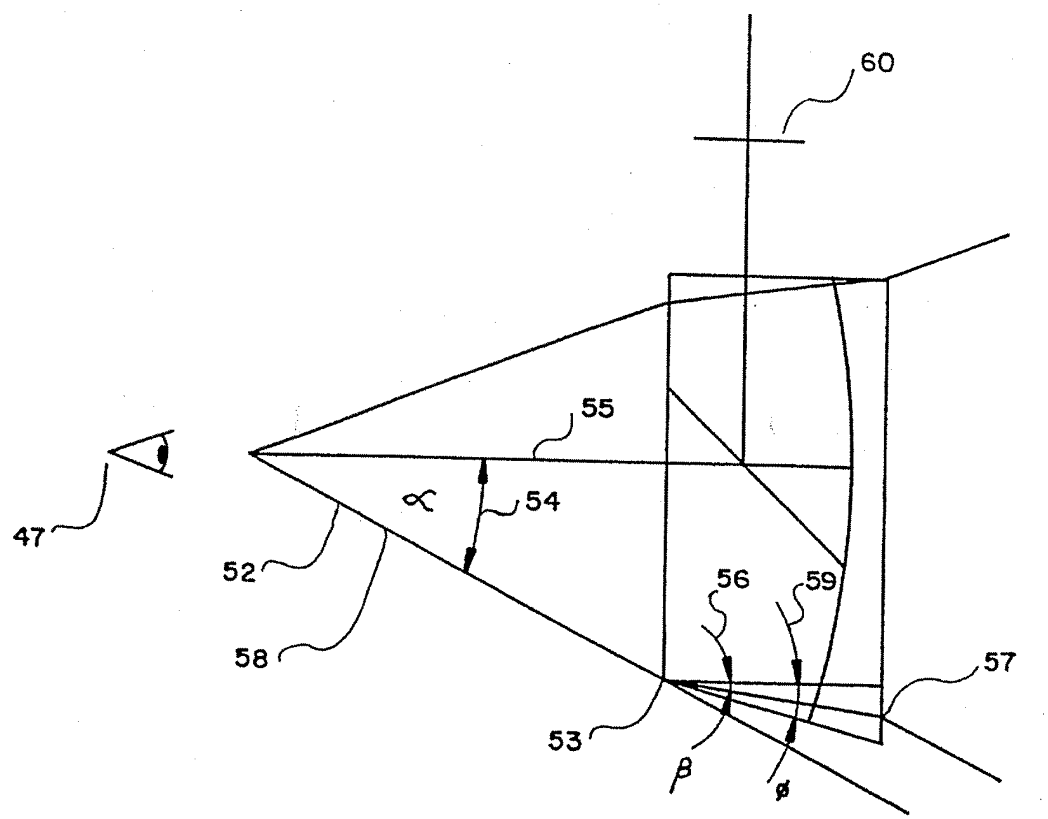

FIG. 5

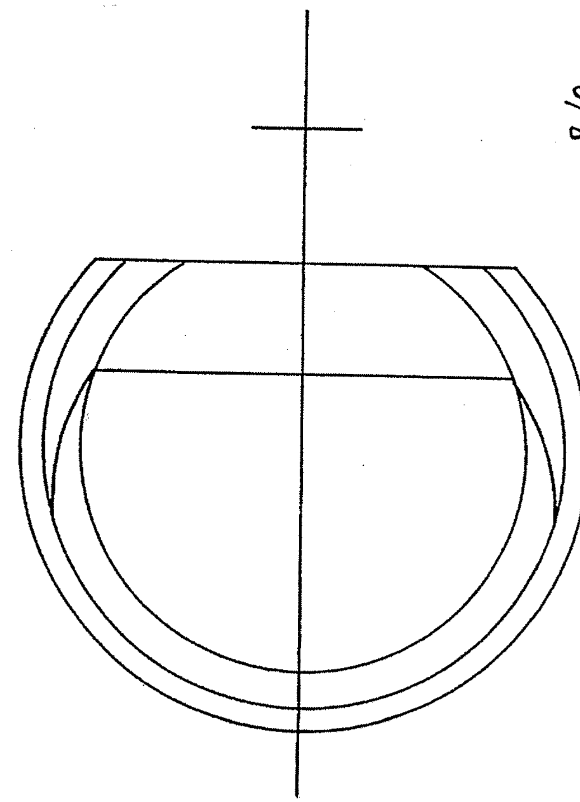

FIG. 6

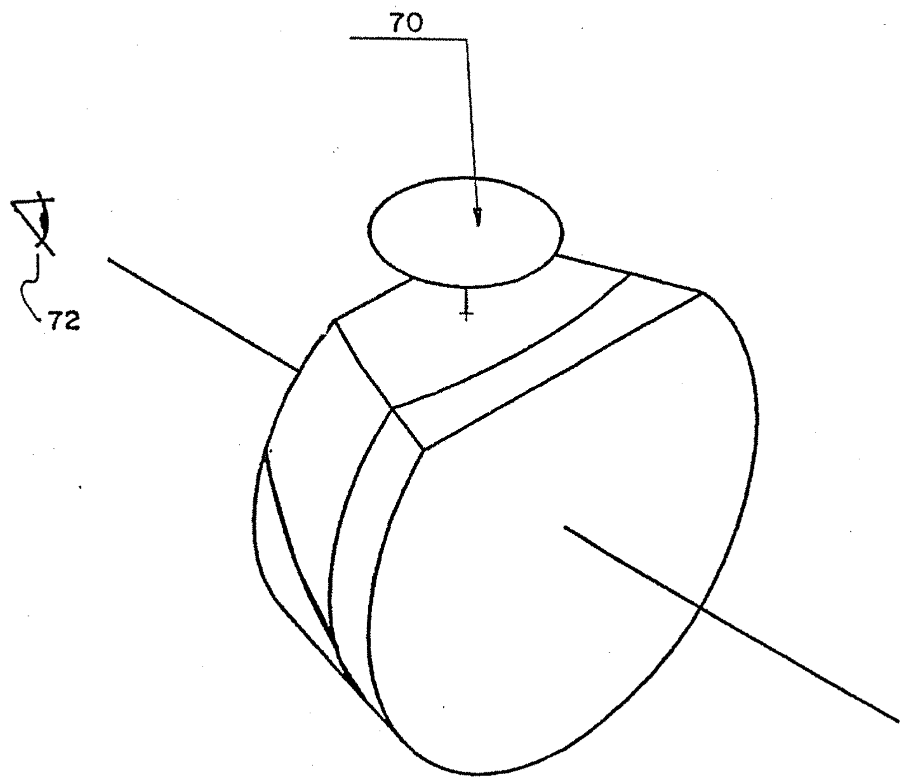

FIG. 7

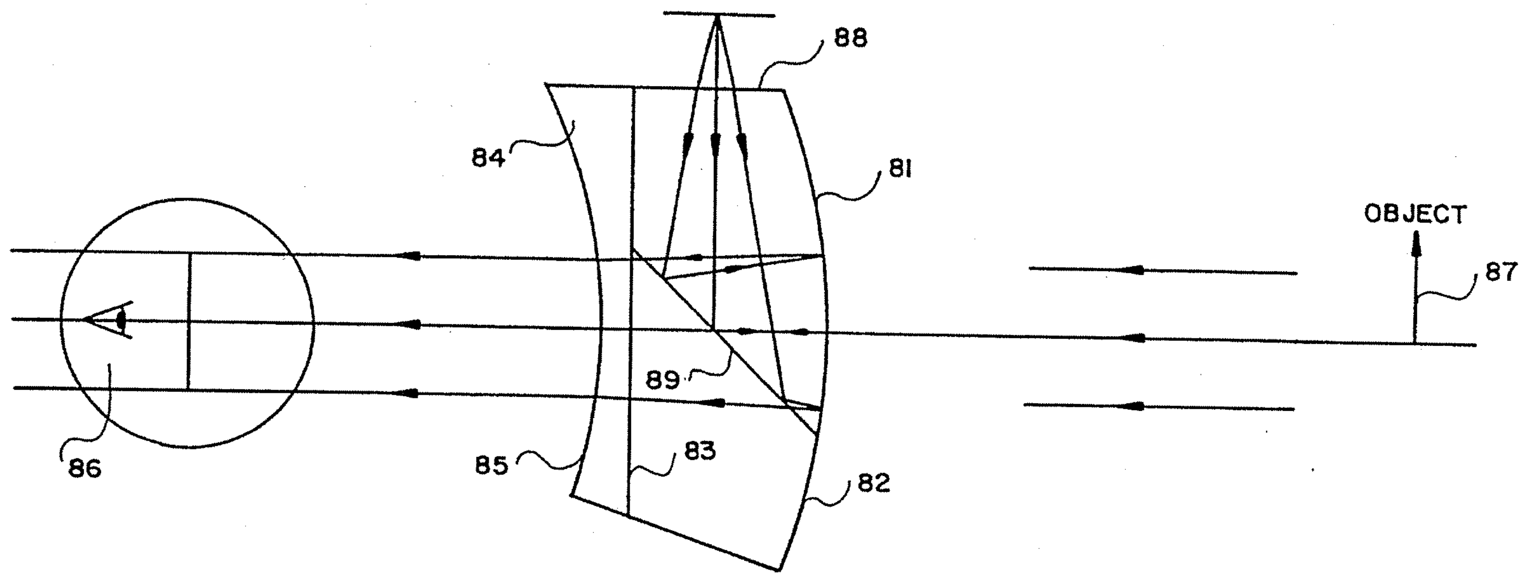

FIG. 8

Optical System

The invention relates to an optical system for the superpositioning of visible information data on a background view viewed by an observer. Systems of the invention are of wide applicability. They may be used in industry where a technician inspects a workpiece by making certain electrical contacts, and simultaneously perceives data from a measuring instrument in his field of view.
The optical system can be used by drivers, who have an open field view of the road and scenery ahead, while critical parameters and warning signals are superpositioned on such view.
The optical system can be used by pilots for viewing the scenery while being provided with required data from one or more instruments. Many other and further applications are in the scope of the present invention.

There exists a variety of optical instruments for the superpositioning of data on a given background. Generally these are head-up display devices which allow simultaneous viewing of the outside world and superpositioning of data important to the viewer.
Amongst instruments of this type there may be mentioned head-up displays used by pilots and drivers.

The characteristics of the display are dictated by a number of requirements, such as: eye relief, exit pupil diameter, field of view of the symbols, weight of the unit and as one of the most important ones, an unimpaired field of view of the outside. Such a system comprises essentially a collimator with a wide field of view and eye relief, larger than the focal length of the system. Such systems are part of Head-Up-Displays (HUDs) and in flight simulators.
Various patents relate to different embodiments of such devices, such as GB 1139269, 2108702 and US 4,269,476.
None of the said systems provide a satisfactory HUD, which provides optimum solutions regarding the requirements set out above.
The present invention provides an improved system of this type.
It is an object of the invention to overcome the drawbacks pointed out above, and to provide a system to enable the viewer to perceive a wide field of view of symbols with minimum obstruction of the outside and large eye relief.
According to the present invention, there is provided an integrated optical system for the simultaneous viewing of scenery and of informative data super-positioned on said scenery, consisting of a lens divided into two parts by a beam splitter, said lens having a first surface facing the viewer, and a second, partially reflecting convex surface on the main optical axis, defining a partially reflecting concave mirror facing the first surface, said lens having a third surface parallel to the main optical axis or at an acute angle therewith, facing the source of the superpositioned informative data, said beam splitter extending from the upper part of the first surface to the lower part of said concave mirror, so that the source of the informative data is at the focus of the said concave surface, so that the beam coming from the data source enters through the third surface, is reflected by the beam

splitter toward the said partially reflecting concave mirror and from this via the beam splitter to the first surface and from this to the eye of the viewer, who simultaneously views the said informative data and the said scenery through the lens, including the beam splitter, along the main optical axis.

The present invention provides a system of the optical on-axis type, which is based on an integral optical member where the component resulting in collimation is a spheric mirror arranged along the optical axis.

In a preferred embodiment, the main component of the system is a block-shaped member made of transparent material (glass, acrylic) in a doublet, the shape of which, when looked through it, has no optical power. This doublet is polished at its upper surface close to the display - the secondary object - and is preferably polished at the periphery in conical form, where the small base is close to the eye and forms part of the positive lens of the doublet. The doublet comprises two lenses, one positive like a plano-convex lens, and a negative one, like a plano-concave one. The positive lens is made of two components, with an inclined plane between them which serves as beam splitter. The negative lens of the doublet, having a radius identical with that of the first member, is provided with a partially light - transmissive and partially light-reflective coating such as a dichroic coating or a holographic coating. Illumination originating from the display which is positioned at the focus of the curved mirror, enters the doublet at its upper part, and is partially reflected by the beam splitter in the direction of the mirror. The mirror reflects the illumination as parallel beam via the beam splitter which passes it in the direction of the external surface of the doublet towards the eye of the viewer.

The exit pupil is positioned near the center of the curvature of the mirror. In this case, when the lens is not in air, the center of curvature is the center of curvature as it appears after refraction by the optical surface which is close to the eye of the viewer.

A number of embodiments of the invention will now be illustrated by way of example with reference to the enclosed schematical Figures, which are not according to scale and in which:

Fig. 1a and 1b set out systems according to the prior art;

Fig. 2 is a side view of the most simple embodiment of the invention;

Fig. 3 is a side view of another embodiment, similar to that of Fig. 3, but with zero optical power

Fig. 4 is an embodiment of a doublet lens system of the invention

Fig. 5 illustrates the outoff angle of the conus

Fig. 7 is of a perspective view of a doublet of the invention.

Fig. 8 is a side view of another embodiment, with the negative lens bonded to the positive one at the surface close to the viewer;

In Fig.1a the system comprises two mirrors, a spheric one 11, which serves as collimator by reflection and window without optical power in transmission. The second mirror 12 serves as beam splitter. The illumination originating from the display surface 13 is directed at the beam splitting mirror 12, and is reflected from same in the direction of the spheric mirror 11. The spheric mirror serves as a collimator and reflects the illumination in collimated form in the direction of the splitting mirror 12 which directs it at the eye 14 of the pilot or viewer, which is located close to the center 15 of the mirror. This system has a number of mechanical and optical drawbacks; it requires a highly accurate mechanical mounting of the components relative each other, and such complicated mountings which are required tend to obstruct at least part of the view. Even a small obstruction in the vicinity of the eye obstructs an appreciable angle of view.

In such a system the eye is located at the center of curvature of the mirror, R, and the display is at half this distance, as the length of focus of a spheric mirror is half its radius, R/2. The beam splitter divides the focal distance into two, the horizontal axis x and the vertical one y, so that $x + y = R/2$. Y is in this case the height of the display from the optical axis.

The desire is to make the height as large as possible to decrease the obstruction of the upper part of the outside field of view. As the height is also a function of the distance to the splitter, so the farther the display will be, the symbols field of view will decrease. With existing parameters of a vertical field of view , the eye relief, from the last surface, will be at a distance E, the diameter of the exit pupil ϕ and the thickness of the member T, it can be shown that:

1 $Xmin = T - \phi/2 - E.tng.(\alpha)$

2 $Ymax = R/2 - Xmin$

3 $R/n = E + T/n$

4 $R = n.E + T$

When we introduce (4) into (2) there is obtained

$$Y_{max} = n \,.\, E/2 + \frac{T}{2} - X_{min}$$

thus from this it is clear that the larger n will be, the value of Y_{max} will become larger and thus also the outside field of view will increase in a corresponding manner. Fig.1b also describes a device according to the prior art. This is based on a back surface mirror which is part of a solid transparent body. Illumination originating from 21 is directed at the input surface 22 of this body and continues to beam splitter 23, passing through same without reflection, arrives at mirror 24, the optical axis

of which is perpendicular to the axis of the central field of view, is reflected in the direction of the beam splitter 23 and returns in the direction of the eye of the viewer, 26. This version overcomes some of the drawbacks of the device of Fig. 1a, but it has certain problems.
As the axis of the spherical mirror is perpendicular to the main optical axis, its projection blocks the angle designated as 25 from view. In order to obtain a larger field of view, the block has to be very thick. At certain angles parasitic reflections are apt to occur from the external surfaces of the glass block.

As shown in Fig. 2 an optical system of the present invention comprises a positive lens 30, having a plane surface 31 and a concave one 32 perpendicular to the optical axis 33, said lens being divided into parts 34 and 35 by beam splitter 36, which slopes downwards from the upper side 34 of the lens close to the viewer, and to the lower part of the part 35 of the lens. The concave surface 32 is provided with a coating 32'which permits passage of part of the light and which reflects the other part. There is provided an upper plane surface 37, which is parallel to the axis 33. It may also be at an acute angle with this axis and may be curved.

The image of the data to be superpositioned is projected from surface 38, which is at a focal distance from mirror 32', via surface 37 to beam splitter 36, and from same to mirror 32' which returns it to the direction of the eye of the viewer, 39.

The eye perceives simultaneously the image of 40 through the semi-transparent mirror 32', and thus sees both images simultaneously.

As the surface 32 is a concave one and the surface 31 is a plane one, the image of 40 is perceived in an enlarged manner.

Another embodiment is illustrated with reference to Fig. 3, which differs from Fig. 2 only in that surface 41 is also a concave one, facing the eye of the observer, 39. Due to the fact that both sufaces 32 and 41 are curved ones, the optical power of this lens is zero if the curvature is chosen correctly. This provides a real-life size/image of the object 40.

Fig. 4 is a side view, in section, of a device of the present invention. The main component is a block of transparent material, such as glass or acrylic polymer. This block is made as a doublet, and has zero optical power when one looks through it. This doublet comprises two lenses, a positive one 41, which may be plano-convex and a negative one 42, such as a plano-concave lens.

The positive lens 41 is made up of two parts, 41a and 41b, with an inclined beam splitter 43, between them.

This plane 43 starts at the lower end close to the convex surface 44 which is common to both lenses and extends upwards towards the upper surface 45 of the doublet close to the source of the display. Surface 46, which is opposite the convex surface 44, constitutes the external surface close to the eye 47 of the viewer. The negative lens 42 of the doublet, has a radius of curvature 44a identical to the radius of curvature 44 of the positive lens 41. This surface 44a is provided with a partially reflecting coating such as a dichroic or holographic one which serves as a collimating mirror. The two lenses are attached to each other at surface 44. Illumination originating from the focal plane 50 is directed at the input surface 45 of the doublet which is essentially parallel to the optical viewing axis 51. The illumination arrives at splitter 43 and part is reflected back in the direction of the collimating mirror 44, which is also provided with a partially reflecting coating and returns part of the energy in the direction of splitter 43, which at this stage passes the beam in the direction of the external surface 46 and from there to the eye of the viewer 47, which is located in the area 48, of central curvature of mirror 44. Rays coming from outside view 49 arrive at surface 40 of the optical system, and pass via mirror 44, beam splitter 43, and the second exterior surface 46 to the eye 47.

As the illumination originating from surface 50 is in the focal plane of mirror 44, it reaches the eye 47 of the viewer as a parallel beam and is perceived as if coming from infinity. It is of course possible to change the focus of the system so as to adjust for objects not in infinity.

Fig. 5 and 6 illustrate the exterior shape given to the optical body of the invention, so as to minimize obstructions of part of the outside view when looking through it. Any obstruction in the vicinity of the eye will obstruct a substantial part of the outside world when looking through the optical body.

In order to minimize obstructions, this body has been given an external concial shape so that a ray which behaves as if it came from the eye of the viewer will not encounter obstructions from the exterior surfaces of the body.

With reference to Fig. 5, ray 52 originating from eye 47, in the direction of the lower end 53 of this body makes an angle 54 (α) with the optical axis 55 of the system. This ray is refracted in the transparent body according to Snell's Law and makes an angle 56 (β) with the optical axis and is returned to exit 57 parallel to beam 52. A further ray 58, coming from eye 47 parallel to the first one passes very close to the lower end 53 but is not refracted and continues in a straight direction

without any impediment. The angle 59 of cut of the conus is

$$\beta < \emptyset < \alpha$$

where the best shape is a cut at an angle of

$$\emptyset = \beta/2 + \alpha/2$$

Fig. 6 is a projection of the transparent member. Fig. 7 is a perspective view of an optical body according to the invention according to Fig. 5 where 70 is the image surface, in the focal plane of the mirror, the optical system and the eye 72.

Yet another embodiment is illustrated with reference to Fig. 8, where 81 is a positive lens, with curved partial mirror surface 82, the convex side of which faces the scenery 87. To the plane surface 83 of the lens there is cemented a plano-concave lens 84, of negative power, with the concave surface 85 facing viewer 86. The other elements, like surface 88, and beam splitter 89 are the same as in Fig. 3. The resulting optical power of this lens doublet is zero, and thus the image of 87 is seen in natural size.

CLAIMS:

1. An integrated optical system for the simultaneous viewing of scenery and of informative data superpositioned on said scenery, consisting of a lens divided into two parts by a beam splitter, said lens having a first surface facing the viewer, and a second, partially reflecting convex surface on the main optical axis, defining a partially reflecting concave mirror facing the first surface, said lens having a third surface parallel to the main optical axis or at an acute angle therewith, facing the source of the superpositioned informative data, said beam splitter extending from the upper part of the first surface to the lower part of said concave mirror, so that the source of the informative data is at the focus of the said concave surface, so that the beam coming from the data source enters through the third surface, is reflected by the beam splitter toward the said partially reflecting concave mirror and from this via the beam splitter to the first surface and from this to the eye of the viewer, who simultaneously views the said informative data and the said scenery through the lens, including the beam splitter, along the main optical axis.

2. An optical system according to claim 1, where the surface of the lens facing the viewer is a plane surface.

3. An optical system according to claim 1, where the lens surface facing the viewer is a concave one, so that the optical power of the lens in the direction of the scenery is zero.

4. A system according to any preceding claim, where a further negative lens is cemented to either the first or second surface of the first lens, so that the system comprises a one block unit which consists of a doublet lens of a positive lens and a negative lens bonded at a common

surface.

5. A system according to claim 4, where said further negative lens is cemented to the convex surface of the first lens, facing the scenery, so that the system comprises a one block unit which consists of a doublet lens of a positive and a negative lens bonded at a common curved surface, serving as partially reflecting mirror, with a surface parallel to or at an angle to the optical axis of the doublet, facing the data source, where the positive lens is divided by a beam splitter into an upper and a lower part, which beam splitter extends from the upper part of the exterior surface facing the viewer, close to said inclined surface facing the data source, and which slopes downwards towards the curved surface, said inclined surface being adapted to pass the "data" image to the beam splitter and from same onto the curved mirror.

6. A system according to claim 4, where the negative lens is bonded to the surface of the positive lens facing the viewer.

7. A system according to claim 4, 5 or 6, where the doublet has zero optical power in the direction of view of the scenery.

8. A system according to any preceding claim, where the surface facing the data source is curved.

9. A system according to any preceding claim, where the partially reflecting mirror is a dichroic mirror.

10. An optical system according to any preceding claim, where the effective optical area of the surface facing the scenery is larger than the surface facing the viewer so that the circumference of the lens does not obscure the scenery.

11. An optical system according to claim 11, where the shape of the outer surface of the lens is a segment of a cone such that the base is in the direction of the scenery and the apex lies behind the viewer's eye.

12. A system according to any preceding claim, where the mirror has a spherical, a conical or a toric surface.

13. A system according to any preceding claim, where the reflective surface of the mirror is provided with a multilayer coating or a holographic coating.

14. An integrated optical system for the simultaneous viewing of scenery and informative data superpositioned on said scenery, comprising:

a lens divided into two parts by a beam splitter, said lens having a first surface which in use faces the viewer, and a second, partially reflecting convex surface on the main optical axis defining a partially reflecting concave mirror facing the first surface, said lens having a third surface parallel to the main optical axis or at an acute angle therewith, which in use faces the source of the superpositioned informative data, said beam splitter extending from said first surface in a direction away from said third surface to said concave mirror, so that in use the source of informative data is at the focus of said concave mirror, so that in use the beam coming from the data source enters through the third surface, is reflected by the beam splitter toward said partially reflecting concave mirror and is reflected from the mirror via the beam splitter and the first surface to the eye of the viewer, who in use simultaneously views the informative data and the scenery through the lens, including the beam splitter, along the main optical axis.

15. An optical system according to claim 14, further comprising the features of any of claims 2 to 13.

16. An integrated optical system substantially as hereinbefore described with reference to any of Figures 2 to 8 of the accompanying drawings.

- 16 -

Patents Act 1977 **Ex iner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9324292.3
Relevant Technical Fields (i) UK Cl (Ed.M) G2J (JHU, JBSX1, JB7X16) (ii) Int Cl (Ed.5) G02B	Search Examiner MR C J ROSS Date of completion of Search 13 JANUARY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-16

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2208014 A	(GEC-MARCONI) see especially eyepiece 39	1 and 14 at least
	GB 1584268	(ELLIOTT) see especially Figure 4	1 and 14 at least
	GB 1364496	(RANK) see especially Figures 4, 6, 8	1 and 14 at least
	US 5050962	(THOMSON-CSF) see especially column 4 line 31 on	1 and 14 at least
	US 4830464	(THOMSON-CSF)	1 and 14 at least

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).